TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

PDW PROGRAM STAFF GUIDANCE

Guidance Title: REVIEW OF PILOT STUDY REPORTS FOR MEMBRANE FILTRATION

Rules Affected: Title 30 TAC §290.42(g), §290.104, §290.105, §290.110(b)(1) and §290.111(b)(2)

This PDW Program Staff Guidance revises and replaces the previous PDW Program Staff Guidance titled, Review of Pilot Study Reports for Membrane Filtration that had an effective date of March 1, 2001. The earlier document expires upon the effective date of this document.

Background

Systems using surface water or groundwater under the influence of surface water must achieve at least a 2.0-log (99%) removal of *Cryptosporidium parvuum* oocysts, a 3.0-log (99.9%) removal or inactivation of *Giardia lamblia* cysts, and a 4.0-log (99.99%) removal or inactivation of viruses. Water treatment plants achieve these treatment technique requirements through a combination of physical and chemical barriers.

These treatment techniques are generally achieved at water treatment plants that incorporate coagulation, flocculation, clarification, granular media filtration and disinfection. However, Title 30 TAC §290.42(g) of the Texas Commission on Environmental Quality (TCEQ) rules allows systems to utilize innovative or alternate treatment systems to achieve the treatment technique requirements.

When these innovative or alternate treatment systems are proposed, the rules require a licensed professional engineer to provide pilot test data or data collected at similar full-scale operations demonstrating that the proposed treatment systems will produce water that meets the requirements of Title 30 TAC Chapter 290, Subchapter F, Drinking Water Standards Governing Water Quality and Reporting Requirements for Public Water Systems.

One emerging alternative treatment system that is becoming a cost-effective treatment for many surface water and ground water under the influence of surface water systems is membrane filtration. Membrane filtration units can be installed in lieu of granular media filters at most water treatment plants and, in some cases, can be used in lieu of complete conventional treatment. Normally, these will be of the hollow-fiber (HF) microfiltration (MF) ultrafiltration (UF) types. However, in some cases nanofiltration (NF) and reverse osmosis (RO) membranes are used. While all four types of membranes achieve particulate and microorganism removal, NF and RO membranes can also remove undesirable chemical constitutes and may be used for achieving compliance with state and federal drinking water standards. As membrane filtration has become economically feasible, the TCEQ staff have been receiving an increased number of proposals to pilot and install different types of membrane filtration units.

Purpose of this PDW Program Staff Guidance

This PDW Program Staff Guidance is intended to facilitate consistent and timely reviews of pilot study reports submitted on membrane filtration units by the TCEQ staff and develop a written response for each submittal stating whether the pilot study was acceptable or unacceptable. The pilot study report and the TCEQ's written response will be used by the design engineers to develop the required engineering plans and specifications for the proposed membrane installation. Please note that if NF or RO membranes are being proposed to only remove undesirable chemical constituents, a large portion of this document will not apply.

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Pilot Study Report

A pilot study report contains the results of the pilot study and recommendations for the full-scale design criteria. The purpose of a pilot study report is to provide the TCEQ staff with the results and conclusions of the pilot study, and to facilitate acceptance of the recommendations for the full-scale water treatment plant design. When reviewing a pilot study report, the TCEQ staff must be aware of and consider the following.

I. Acceptance of pilot study data or the proposed full-scale design criteria is not approval for construction of any membrane units for treatment of water for a public water system. Construction of the membrane water treatment facilities may not begin until the TCEQ staff has reviewed and approved the site-specific final engineering plans and specifications for modifications to an existing or a new full-scale water treatment plant.

II. Unless a site-specific request for an exception was received and granted by TCEQ staff, a pilot study must be conducted and data collected for a period of at least **90 days**. At least **30 days** must be conducted under the proposed full-scale pretreatment scheme and membrane flux rate, TMP, backwash parameters and chemical clean-in-place (CIP) procedures. The 30-day simulated full-scale run must be followed by a CIP procedure and at least another tens of operation under the same full-scale operating conditions.

III. The pilot study report must be prepared by the systems's professional engineer, licensed by the Texas Board of Professional Engineers, and accompanied by a cover letter that is signed, sealed and dated.

VI. The TCEQ staff that is reviewing a pilot study report may request a meeting with a responsible official of the public water system or their professional engineer prior to accepting the pilot study report or the proposed design criteria.

V. Each membrane unit tested must be of the same design and contain fibers of the same length and type as will be specified in the full-scale water treatment plant.

VI. As the TCEQ's design capacity and flow reporting requirements are in English Units, the flow rates must be reported in gallons per minute (gpm) or million gallons per day (MGD) and flux rates in gallons per square foot per day (gfd) to facilitate the review process.

VII. Pilot studies are normally conducted in three stages. However, each stage may contain more than one phase of testing. The TCEQ requires pilot studies to be conducted for a period of **at least 90 days** unless a written exception to this requirement was requested and granted. A CIP procedure and direct integrity test must have been conducted prior to beginning each of these three stages of testing.

A. The Stage 1 test period should establish site-specific and full-scale pretreatment operating parameters for each tested membrane unit in regards to pretreatment requirements, specific flux rate, backwash frequency, backwash duration, backwash flow rate, and CIP procedures.

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A selected set of optimized conditions developed under the Stage 1 testing are used to conduct the Stage 2 and 3 testing. If NF or RO membranes are being used in an integrated membrane system to treat only a portion of the water, a blending ratio must be established to achieve compliance with the drinking water standards. Be aware that the Stage 1 test period data may indicate that modifications to the accepted pilot study protocol were required for one or all membrane test units.

B. After the Stage 1 test period, a chemical CIP and direct integrity test must be conducted on each membrane test unit before beginning the second stage of testing. The Stage 2 test period must be for a minimum of **30 days** under each membrane unit's selected set of full-scale operating conditions and verify the conclusions reached from data collected during the Stage 1 test period. For any unscheduled downtime greater than 24 hours, documentation must be included indicating that the TCEQ was contacted to see if the Stage 2 test period needed to be restarted.

All membranes are operated under parameters that consist either of a constant flux rate with a varying transmembrane pressure (TMP) or a constant TMP with a varying flux rate. When a membrane is in operation it continues to have an increase in the fouling that the backwash/backflush/reverse flow cycles do not remove. Once the varying parameter degrades to the manufactures recommended set point, a CIP procedure must be conducted to remove the fouling and restore the operating flux rate and TMP to an acceptable level. If the flux rate or TMP for a membrane unit reached unacceptable levels before the end of the 30-day test period, the engineer or system may have chosen to start a membrane unit's Stage 2 test period over under different simulated full-scale operating conditions. However, they may have chosen to conduct a CIP and direct integrity test and complete the 30-day test period under the same operating conditions. In this case, the CIP duration is less than 30 days and the time out of service must be taken into consideration when calculating the TCEQ's approved net capacity because of the decrease in frequency of CIP procedures.

Please note that Norit uses a chemical cleaning process for their membranes that consists of a series of "chemical enhanced backwash (CEB)" procedures using an acidic solution mixed in with the chlorinated filtrate backwash procedures approximately ever 18 to 20 backwashes in lieu of a single CIP procedures conducted ever 30 days or so. The CEB procedures are approximately 10 to 15 minutes in duration. Also, depending on the feed water quality, other membrane vendors will sometimes use similar procedures conducted at frequencies from once per day to once per week that they refer to as"enhanced filtrate maintenance," "mini CIP" or "chemical soaks" to extend the frequency between their normal CIP procedures. All of these procedures result in time out of production for the membrane units and must be taken into account when calculating the TCEQ's approved net capacity for a specific membrane unit. However, single CIP procedures conducted at a frequency of 30 days, or greater, that results in offline periods of less than four hours per month, do not significantly affect the average daily net production.

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C. The Stage 3 test period must have included a CIP and direct integrity test followed by operating a minimum of **ten days** at the simulated full-scale operating conditions selected for the Stage 2 testing. This is used to establish the % loss of original specific flux, temperature adjusted to 20° C, and determine if any irreversible membrane fouling of each membrane unit has occurred. If the % loss of original specific flux for a specific membrane unit or % of irreversible membrane fouling is determined to be excessive, the selected full-scale operating conditions may result in the TCEQ's approved design capacity being less than is required or desired by the system. A rapid increase in irreversible fouling can result in degradation of net production and premature replacement of membrane units in a full-scale membrane installation. Under these conditions the reviewing TCEQ staff should include comments in the pilot study review letter stating that the pilot study indicates that the simulated full-scale operating conditions for the specific membrane unit indicates rapid fouling at the selected operating conditions and the potential for rapid degradation of the net production and a short membrane life. Also, the TCEQ's accepted net production for an individual membrane unit may need to be reduced. The designing engineer must address these concerns in the engineering plans and specifications submitted for the full-scale design.

D. The TCEQ staff must evaluate the data from the three stages of testing to determine if the pilot study was acceptable for the TCEQ to review engineering plans and specifications for a proposed full-scale membrane installation and issue a TCEQ approved net capacity rating for a full-scale membrane filtration installation. The operating parameters during the Stage 2 testing are used to determine the total time a membrane unit would actually be in filtrate production, time in backwash/backflush/reverse flow cycles, and any other production limiting events during a 30-day period. This data is used to calculate the TCEQ's accepted net capacity rating at 20° C. However, the data from the Stage 1 and 3 testing must also be reviewed to determine what, if any, raw water conditions or tested operating parameters will need to be addressed in the site-specific engineering design and specifications.

If the consulting engineer and public water system has already selected one of the piloted membranes, only the pilot study data for the selected membrane will need to be submitted, reviewed and responded to in writing. The TCEQ staff's written response to the submitted pilot study report will be used by TCEQ staff to review the full-scale engineering design and specifications.

VIII. The pilot study report must contain the following background information.

A. A copy of a TCEQ accepted pilot study protocol, if any. If the prior acceptance of a site-specific pilot study protocol from the TCEQ staff was not received, the pilot study report must indicate that the study was conducted in accordance with a pilot study protocol and include a copy of the pilot study guidelines. (See PDW Program Staff Guidance: Review of Pilot Study Protocols for Membrane Filtration)

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B. General information about the site where the pilot study was conducted.

1. The name of the public water system and water treatment plant(s) involved in the pilot study.
2. The Public Water System I.D. number.
3. The name of the raw water source or sources proposed for treatment by membrane filtration and the water rights allocation.
4. A USGS 7.5-minute quadrangle map showing the location of the intake structure(s) used during the pilot study. If the location of the intake for the pilot study differs from that of the existing water treatment plant, or that of the proposed full-scale membrane water treatment plant, both locations must also be shown on the map.
5. A schematic of the pilot plant that shows chemical feed points, pretreatment facilities, pilot equipment, flow meters, and monitoring points.

C. The pilot study report must contain the following information for each membrane module that was evaluated.

1. Membrane manufacturer's name;
2. Type of membrane (MF, UF, NF, RO);
3. Documentation that the piloted membrane unit conformed to American National Sanitation Institute/National Sanitation Foundation (ANSI/NSF) Standard 61 and has been certified by a testing organization accredited by ANSI;
4. Material the membrane fiber is constructed of;
5. Length of membrane fiber;
6. Surface area of the feed water side of the membrane module/element;
7. Flow direction (inside out or outside in)
8. Nominal and maximum pore sizes;
9. Oxidant resistance;
10. Water temperature operating range;
11. Feed water turbidity operating limit;
12. Method of operation (dead-end or crossflow);
13. Maximum recommended instantaneous filtrate flux rate;
14. Maximum allowable TMP;
15. The required direct integrity test pressure to detect a defect as small as 3.0 microns (see the most recent draft or adopted version of the ASTM document titled, Standard Practice for integrity Testing of Water Filtration Membrane Systems);
16. Concentration factor (CF), defined as a measure of the increase in concentration of the contaminant that could occur on the high pressure side of the membrane relative to the raw water;
17. Flow from the smallest breach (3.0 microns), at the maximum recommended instantaneous filtrate flux rate, that can be detected by the direct integrity test; and,

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18. Log removal value (LRV) as defined in EPA guidance (Also, see PDW Program Staff Guidance titled, Membrane Filtration Terms Defined).

IX. A pilot study report must provide the following CIP (and any other chemical cleaning procedures such as "mini CIP," CEB and chemical soaking procedures) data for each membrane module that will be considered for the full-scale water treatment plant.

A. All chemicals used and their concentrations;

B. Documentation that all chemicals used conformed to ANSI/NSF Standard 60 and have been certified by a testing organization accredited by ANSI;

C. Flow rate;

D. Duration (time offline);

E. Quantity of filtrate water used;

F. Disinfectant residual (if applicable);

G. pH of the chemical solution;

H. Temperature of the chemical solution;

I. Procedure;

J. Disposal method of chemical waste; and,

K. The expected chemical cleaning frequency for the full-scale membrane water treatment plant.

X. The TCEQ requires continuous/indirect integrity monitoring of the filtrate water of each manufacturer's membrane test unit. For removal credit of particulates and microorganisms, this may be accomplished by continuous on-line particle counters and monitors or Hach FilterTrak (FT660) laser turbidimeters (for individual membrane rack/tank filtrate/permeate only). Any other method must have received the TCEQ staff's acceptance prior to beginning the pilot study.

XI. The pilot study report must include a list of the analytical methods and equipment used during the pilot study and describe the calibration procedures and frequency for the analytical equipment and flow meters.

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A. Some acceptable analytical procedures, calibration procedures, frequency, and accuracy of measurement requirements are found in Title 30 TAC §290.46(s), §290.110(d), §290.111(d) and §290.119.

B. If ozone was used, residuals must have been measured and reported to a minimum accuracy of ± 0.02 milligrams per liter using the Indigo Method as specified in Standard Methods, 20th Edition, 4500-O_3B.

C. Benchtop particle counters/monitors must have been calibrated as specified in the EPA/NSF Equipment Verification Testing (ETV) Plan: Membrane Filtration for the Removal of Microbiological and Particulate Contaminants, Chapter 13.0, Section 13.8.3 prior to startup of the pilot study and again before beginning the simulated full-scale plant test portion of the pilot study. Benchtop particle counters/monitors must be equipped with a sensor capable of identifying particle sizes in the 2 - 15 micron range and reporting the total count with a coincidence error of less than 10%.

D. On-line particle counters/monitors must have been calibrated according to the manufacturer's specification prior to the startup of the pilot study and verified weekly against the results of a calibrated benchtop particle counter/monitor. On-line particle counters and monitors must be equipped with a sensor capable of identifying particle sizes in the 2 - 15 micron range and reporting the total count at five-minute intervals for this range with a coincidence error of less than 10%.

XII. The pilot study report must contain the following graphs for each membrane unit being considered for full-scale installation. Each of the graphs must show the time the data was collected on the x-axis and the results of the measurements on the y-axis. The scale of each axis must be such that data at **four hour** intervals and all chemical cleaning events can be clearly identified.

A. A graph showing the **daily** turbidity levels (using a Hach 1720C or TCEQ accepted equivalent) of the raw water **and any time there is a change that affected the operating parameters**;

B. A graph showing the total particle counts in the 2 to 15-micron range **at 15-minute intervals** for the feed water and **at five-minute intervals** for the filtrate/permeate water;

or

A graph showing the turbidity levels **at 15-minute intervals** for the feed water (using a Hach 1720C or TCEQ accepted equivalent) and **at five-minute intervals** for the filtrate/permeate water (using a Hach FilterTrak Model 660);

C. A graph showing filtrate/permeate flux rates and corresponding TMP **at four-hour intervals**;

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D. A graph showing the **daily** filtrate/permeate flux rates and corresponding feed water temperatures;

E. A graph showing the **daily average** specific flux rates (adjusted to 20° C) and % recovery of specific flux; and,

F. A graph showing the % loss of original specific flux rate for each Stage 2 filtrate run and the corresponding feed water turbidity levels during the run.

XIII. A pilot report must contain each of the following data summary tables. Each of the tables must contain the number of data points collected, the range of data values (i.e., the maximum and minimum values), the average value, and the 95th percentile value if more than 10 data points were collected.

A. A "log removal table" summarizing the feed water and filtrate/permeate water data and the level of **daily** removal achieved for each of the following parameters.

1. Turbidity;
or
Particle counts;
2. The calculated Log Removal Value; and,
3. *E. coli* (if that data was collected).

B. A "membrane performance table" summarizing the following operating conditions and each membrane module's performance during the pilot study.

1. Feed water flow rate;
2. Filtrate water flow rate;
3. Recycle flow rate (if applicable);
4. Reject flow rate (if applicable);
5. Filtrate flux;
6. TMP;
7. Feed water temperature;
8. Specific flux (adjusted to 20° C);
9. % recovery of specific flux after a CIP;
10. Each direct integrity test's beginning pressure, ending pressure and duration;
11. The calculated maximum log removal based on: $LR_{max} = LOG[Q_{filtrate} / CF \times Q_{breach}]$ (Where, $Q_{filtrate}$ is the actual design flow, CF is the concentration factor, and Q_{breach} is the flow rate from a 3.0-micron breach in a module's components as detected by the required direct integrity test);
12. % loss of original specific flux due to irreversible fouling;
13. Backwash frequency;

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14. Backwash duration; and,
15. Backwash flow rate.

C. A "water quality table" summarizing the results of the following water quality analyses.

1. Raw water total hardness as calcium carbonate;
2. Raw water total alkalinity;
3. Raw water iron, manganese and aluminum;
4. Raw water total dissolved solids (TDS), total suspended solids (TSS) and conductivity;
5. Raw water pH;
6. Raw water algae count;
7. Feed water pH (if it was different from raw water);
8. Feed water algae count (if it was different from the raw water count);
9. Filtrate water pH;
10. Raw and filtrate TOC levels (if a coagulant was fed); and,
11. Filtrate water conductivity or TDS (if NF or RO membranes were piloted).
12. If NF or RO membranes are being used to remove regulated chemical constituents, include the calculations for determining a blending ratio that will produce a finished water quality that meets all state drinking water standards.

XIV. If a disinfectant was applied during the study, the pilot study report must include a "disinfection data table" for each of the following that includes the number of data points collected, the range of data values (i.e., the maximum and minimum values), and the average value.

A. Each disinfectant and application point;

B. Disinfectant dosage;

C. All disinfectant residual levels;

D. Total Trihalomethanes (TTHM);

E. Haloacetic Acids (HAA5);

F. Chlorite (if chlorine dioxide was used); and,

G. Bromate (if ozone was used).

XV. A pilot study report must include a detailed description of the site conditions and each membrane unit's testing. The following information must be included in this description.

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A. A description of the raw water source, the raw water intake and all pretreatment facilities.

B. A description of the manufacturer's required membrane preconditioning method that occurred prior to the pilot study.

C. All rainfall events on the watershed during the pilot study.

D. If conventional pretreatment (coagulation, flocculation, clarification) was not provided in the pilot study, then the pilot study period must have included at least one raw water spike associated with a major rainfall event or a turbidity spike created using a turbidity spiking technique. The raw water spike or turbidity spike must be representative of the source's historical raw water turbidity highs. The method of turbidity spiking must have received the TCEQ staff's prior approval and be included in the pilot study report.

E. A description of how the results of the initial Stage 1 testing resulted in the selected Stage 2 simulated full-scale operating conditions piloted for each membrane unit.

F. A description of any equipment failures and any resulting time delays.

G. A detailed analysis of the pilot study data for each membrane unit.

END

REFERENCES:

1. ASTM 2001 Draft: STANDARD PRACTICES FOR INTEGRITY TESTING OF WATER FILTRATION MEMBRANE SYSTEMS
2. AWWA MEMBRANE PRACTICES FOR WATER TREATMENT
3. AWWA WATER TREATMENT PLANT DESIGN
4. AWWA Manual: REVERSE OSMOSIS AND NANOFILTRATION (M46)
5. EPA's LT2ESWTR Draft Language
6. NSF Equipment Verification Testing Plan: MEMBRANE FILTRATION FOR THE REMOVAL OF MICROBIOLOGICAL AND PARTICULATE CONTAMINANTS

April 1, 2004
Effective Date

Expiration Date

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If no formal expiration date has been established for this staff guidance, it will remain in effect until superceded or canceled.